

PV inefficiency and overlapping photons in the PR

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Abstract

Using a combination of results from GEANT3, FastMC and calculations, I investigated the possible loss of PV inefficiency due to overlapping photons in the PR. It doesn't look like it should be a problem.

1 Method and results

Toshio asked a while ago about photons in the PR 'hiding' in the shower of another photon. Vlodya also asked me about this last week. I did some calculations to estimate the magnitude of the effect.

The model is that if a low energy photon (γ_1) deposits energy only in a single PR scintillator and that slab is part of the shower of another photon (γ_2), then we wouldn't be able to veto γ_1 .

From the KOPIO GEANT MC v07.8, the probability that a 10 MeV photon leaves > 1 MeV visible energy in < 2 slabs is $\mathcal{P}_{<2} = 0.355 \pm 0.006$ based on 10000 incident photons. I am assuming that if > 1 slabs are hit, then there is a hit in each of the orthogonal views (x and y), so that an overlap in y can be resolved by the hit in x , for example. Laur pointed out that this number seems inordinately large for an e^+e^- pair produced in an almost entirely active detector. This result is for single-ended PR readout with an assumed PR scintillator attenuation length of 200 cm. The photons are all incident ~ 100 cm from the readout end so only 61% of the light makes it to the readout. If the attenuation length is set to 2 km, then $\mathcal{P}_{<2} = 0.015 \pm 0.015$ based on 100 incident photons. Thus $\mathcal{P}_{<2} = 0.355 \pm 0.006$ can be regarded as the probability if one readout end is unavailable, and there are indications that we could do much better. Note that I assume that if γ_1 leaves energy in the CAL, then it can be vetoed; that is, events which left energy in the CAL were excluded from this study.

The probability that γ_1 interacts deeper in the PR than γ_2 is $\mathcal{P}_{\text{deeper}} = 0.385$ assuming that γ_2 interacts in the PR based on the assumption that the interaction probability goes as $e^{-7z/9}$ where z is the depth in the PR in radiation lengths.

From Kp2 events in the FastMC, the probability that $\min(|x(\gamma_1) - x(\gamma_2)|, |y(\gamma_1) - y(\gamma_2)|) \equiv d < 11$ cm is $\mathcal{P}(d < 11) = 0.063$ where $x(\gamma_1)$ and $y(\gamma_1)$ are the x and y positions of γ_1 at the front of the PR. If we require $d < 22$ cm, then the probability increases by about a factor of 2 as shown in Figure 1.

Threshold (MeV)	$\mathcal{P}_{<2}(10)$	$\mathcal{P}_{<2}(30)$	$\mathcal{P}_{<2}(50)$
0	$(1.0 \pm 0.4) \times 10^{-3}$	$(0.50 \pm 0.35) \times 10^{-3}$	0
0.4	$(4.4 \pm 0.9) \times 10^{-3}$	$(0.50 \pm 0.35) \times 10^{-3}$	0
1.0	0.355 ± 0.006	$(2.5 \pm 0.8) \times 10^{-3}$	0
3.0	1	0.987 ± 0.002	0.946 ± 0.004
$\mathcal{P}(\text{overlap})$	0.0086	6×10^{-5}	$< 2.4 \times 10^{-5}$
$\bar{\epsilon}_{\text{PV}}$	0.08	2×10^{-3}	1.3×10^{-3}

Table 1: $\mathcal{P}_{<2}(E)$ is the fraction of photons with incident energy E in MeV with less than two PR slabs above the stated energy threshold. There were 10000 incident photons for $E = 10$ and 30 MeV and 1000 photons with $E = 50$ MeV. $\mathcal{P}(\text{overlap})$ is defined in the text. $\bar{\epsilon}_{\text{PV}}$ is the current estimate (PV6 in the FastMC) of the PV inefficiency for normally incident photons.

Combining all these factors

$$\mathcal{P}_{<2} \times \mathcal{P}_{\text{deeper}} \times \mathcal{P}(d < 11) = \mathcal{P}(\text{overlap}) \quad (1)$$

$$0.355 \times 0.385 \times 0.063 = 0.0086 \quad (2)$$

where $\mathcal{P}(\text{overlap})$ is the probability that γ_1 cannot be used as a veto.

The assumed photon veto inefficiency for a normally incident 10 MeV photon in using the PV6 model in the FastMC is 0.08 so it looks like we are safe by a factor of 10.

Similar calculations for 30 and 50 MeV incident photons are shown in Table 1.

2 Discussion

Based on the stated assumptions, it looks like we should have no loss of PV inefficiency due to shower overlaps in the PR.

These results depend crucially on the reconstruction algorithm for photons in the PR, CAL and EPV. Resolving a distinct energy deposit of ~ 1 MeV amidst an extended shower of hundreds of MeV is non-trivial. As Marvin pointed out, the self-veto rate will be a sensitive function of how showers are recognized and defined.

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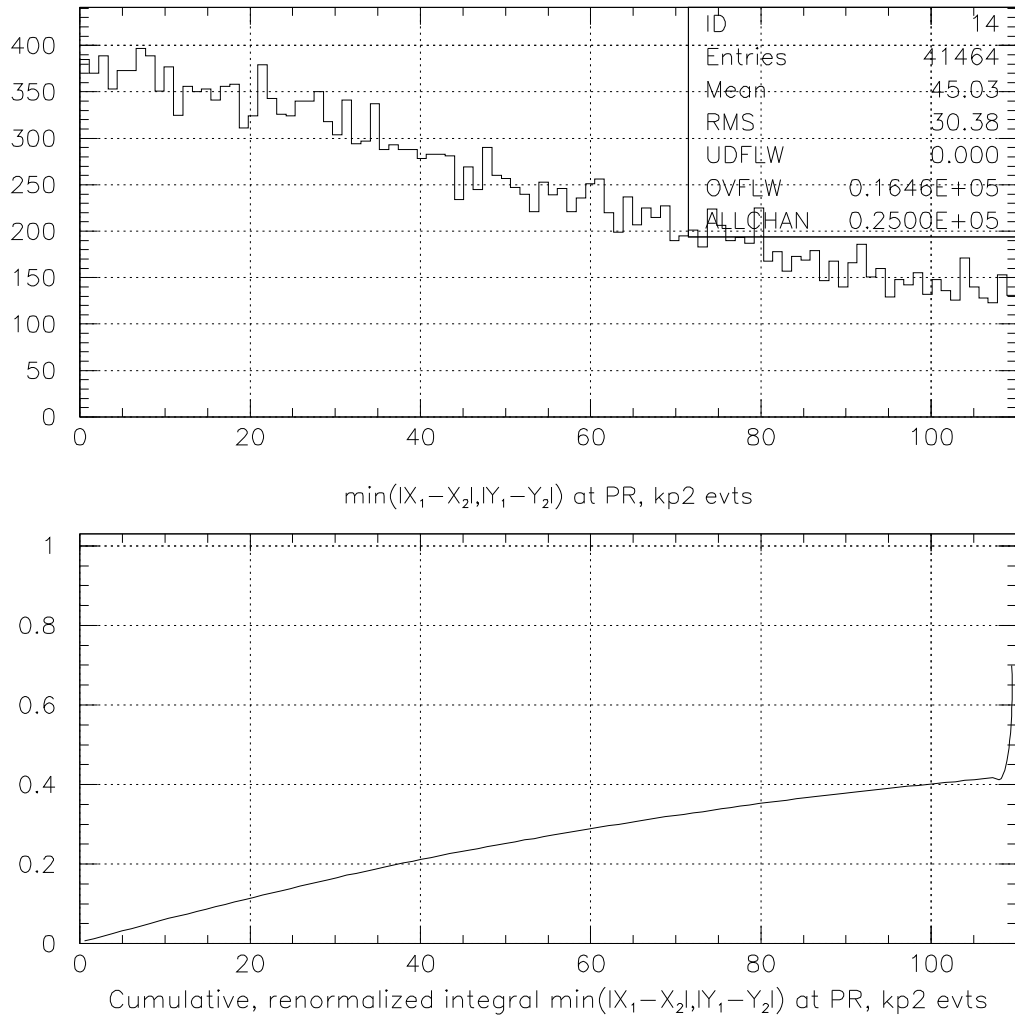


Figure 1: Upper: The minimum distance in x or y between Kp2 photons at the front of the PR. Lower: The cumulative integral of the minimum distance. The integral has been normalized to the total number of photon pairs in the Kp2 sample.